

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**



Europäisches Patentamt
European Patent Office
Office européen des brevets

⑪ Publication number:

O 100 119
A1

⑫

EUROPEAN PATENT APPLICATION

⑬ Application number: 83201040.9

⑭ Int. Cl.: C 07 D 301/12, C 07 D 303/04

⑮ Date of filing: 13.07.83

⑯ Priority: 28.07.82 IT 2260882

⑰ Applicant: ANIC S.p.A., Via Ruggena Settimo, 55,
I-80139 Palermo (IT)

⑲ Date of publication of application: 08.02.84
Bulletin 84/8

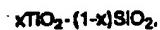
⑳ Inventor: Neri, Carlo, Via Europa 32, I-20097 S.Donato
Milanese (Milan) (IT)
Inventor: Antofoi, Bartolomeo, Via Ravenna 64, I-20139 -
Milan (IT)
Inventor: Esposito, Antonio, Via Libertà 70,
I-20097 S.Donato Milanese (Milan) (IT)
Inventor: Buonomo, Franco, Via Trento 4,
I-20097 S.Donato Milanese (Milan) (IT)

㉑ Designated Contracting States: AT BE CH DE FR GB LI
LU NL SE

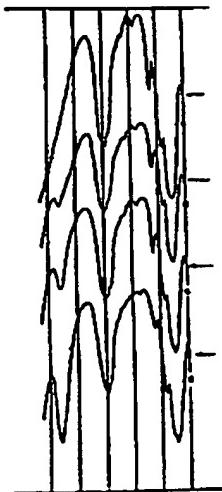
㉒ Representative: Roggero, Sergio et al, Ing. Barzani &
Zanardo Milano S.p.A. Via Borgonuovo 10,
I-20121 Milano (IT)

㉓ Process for the epoxidation of olefinic compounds.

㉔ A process for the epoxidation of olefinic compounds,
consisting of reacting said compounds with hydrogen peroxide
either introduced as such or produced by substances capable
of generating it under the reaction conditions, in the presence
of synthetic zeolites containing titanium atoms, of general formula:



where x lies between 0.0001 and 0.04, and possibly in the presence
of one or more solvents, operating at a temperature of
between 0° and 150°C, and at a pressure of between 1 and 100
ata.



EP O 100 119 A1

0100119

This invention relates to a process for the epoxidation of olefinic compounds by means of hydrogen peroxide either introduced as such or produced by substances capable of generating it under the reaction conditions, in the presence of synthetic zeolites containing titanium atoms.

Hydrogen peroxide when in the presence of suitable derivatives of transition metals (Mo, V, W, Ti etc.) is known to be able to attack olefinic double bonds, with the formation of epoxides and/or glycols.

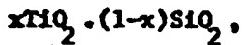
10 The glycol quantity present is a function of the quantity of water introduced with the hydrogen peroxide, and consequently in order to obtain high epoxide selectivity it is necessary to use very concentrated hydrogen peroxide (> 70%), with obvious safety problems due to the violent decomposition of the hydrogen peroxide, or to 15 use solvent mixtures able to azeotropically remove the water accompanying the H_2O_2 and the water of reaction.

It is likewise known that polar solvents (of which water is one) kinetically retard the epoxidation reaction.

We have surprisingly found that a synthetic zeolite containing 20 titanium atoms is able to selectively epoxidise the olefins with high epoxide yields even though working with hydrogen peroxide in aqueous solution, and even when diluted to a low concentration such as 10% (the usual being 10-70%).

The subject matter of the present invention is a process for the 25 epoxidation of olefinic compounds consisting of reacting said compounds with hydrogen peroxide either introduced as such or produced by substances capable of generating it under the reaction conditions, in the presence of synthetic zeolites containing

titanium atoms (titanium silicalites), of the following general formula:



where x lies between 0.0001 and 0.04, and possibly in the presence of one or more solvents.

The synthetic zeolites used for the epoxidation reaction are described in Belgian patent 886,812, of which we repeat some points illustrating the material and relative method of preparation.

The composition range of the titanium silicalite expressed in terms

of molar ratios of the reagents is as follows:

Molar ratio of reagents	preferably
-------------------------	------------

$\text{SiO}_2/\text{TiO}_2$	5-200	35-65
-----------------------------	-------	-------

OH^-/SiO_2	0.1-1.0	0.3-0.6
----------------------------	---------	---------

$\text{H}_2\text{O}/\text{SiO}_2$	20-200	60-100
-----------------------------------	--------	--------

Me/SiO_2	0.0-0.5	0
--------------------------	---------	---

RN^+/SiO_2	0.1-2.0	0.4-1.0
----------------------------	---------	---------

RN^+ indicates the nitrogenated organic cation deriving from the organic base used for the preparation of the titanium silicalite (TS-1).

Me is an alkaline ion, preferably Na or K.

The final TS-1 has a composition satisfying the formula

$x\text{TiO}_2 \cdot (1-x)\text{SiO}_2$, where x lies between 0.0001 and 0.04, and preferably between 0.01 and 0.025. The TS-1 is of the silicalite type, and all the titanium substitutes the silicon.

The synthetic material has characteristics which are shown up by X-ray and infrared examination.

The X-ray examination is carried out by means of a powder diffractometer provided with an electronic pulse counting system, using the radiation

CuK $\bar{\alpha}$. The titanium silicalites (TS-1) are characterised by a X-ray diffraction spectrum as shown in Figure 1b. This spectrum is similar overall to the typical spectrum of silicalite (Figure 1a), however it has certain clearly "single" reflections where double reflections
5 are evident in the pure silicalite spectrum.

Because the spectral differences between TS-1 and silicalite are relatively small, special accuracy is required in the spectral determination. For this reason TS-1 and silicalite were examined by the same apparatus, using Al₂O₃ as the internal standard.
10

Table 1 shows the most significant spectral data of a TS-1 where $x = 0.017$, and of a pure silicalite.

The constants of the elementary crystalline cell were determined by the minimum square method, on the basis of the interplanar distances of 7-8 single reflections lying within the range of
15 10-40° 2θ.

A large proportion of the interplanar distances of TS-1 are tendentially greater than the corresponding distances of pure silicalite, although only slightly, which is in accordance with the larger predictable value of the Ti-O bond distance relative to that
20 of the Si-O bond distance.

Passage from a double reflection to a single reflection is interpreted as a change from a monoclinic symmetry (pseudo orthorhombic) (silicalite) to an effective orthorhombic symmetry, "titanium silicalite" (TS-1). In Figure 1, the most apparent aforesaid
25 spectral differences are indicated by arrows.

INFRARED EXAMINATION. TS-1 shows a characteristic absorption band at about 950 cm⁻¹ (see Figure 2, spectra B, C and D) which is not

present in the pure silicalite spectrum (Figure 2, spectrum A), and is also absent in titanium oxides (rutile, anastase) and in alkaline titanates.

Spectrum B is that of TS-1 with 5 mol% of TiO_2 , spectrum C is that of TS-1 with 8 mol% of TiO_2 , and spectrum D is that of TS-1 with 2.3 mol% of TiO_2 .

As can be seen from Figure 2, the band intensity at approximately 950 cm^{-1} increases with the quantity of titanium which substitutes the silicon in the silicalite structure.

10 MORPHOLOGY. From a morphological aspect, TS-1 is in the form of parallelepipeds with chamfered edges. A X-ray microprobe examination has shown that the titanium distribution within the crystal is perfectly uniform, thus confirming that the titanium substitutes the silicon in the silicalite structure, and is not present in other forms.

15 The process for preparing titanium silicalite comprises the preparation of a reaction mixture consisting of sources of silicon oxide, titanium oxide and possibly an alkaline oxide, a nitrogenated organic base and water, the composition in terms of the molar reagent ratios being as heretofore defined.

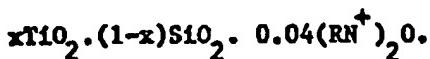
20 The silicon oxide source can be a tetraalkylorthosilicate, preferably tetraethylorthosilicate, or simply a silicate in colloidal form, or again a silicate of an alkaline metal, preferably Na or K.

The titanium oxide source is a hydrolysable titanium compound 25 preferably chosen from $TiCl_4$, $TiOCl_2$ and $Ti(alkoxy)_4$, preferably $Ti(OCH_2CH_3)_4$.

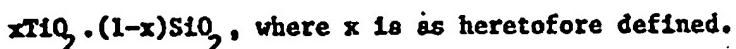
The organic base is tetraalkylammonium hydroxide, and in particular

tetrapropylammonium hydroxide.

The reagent mixture is subjected to hydrothermal treatment in a autoclave at a temperature of between 130 and 200°C under its own developed pressure, for a time of 6-30 days until the crystals of 5 the TS-1 precursor are formed. These are separated from the mother solution, carefully washed with water and dried. When in the anhydrous state they have the following composition:



The precursor crystals are heated for between 1 and 72 hours in air 10 at 550°C to completely eliminate the nitrogenated organic base. The final TS-1 has the following composition:



Chemical and physical examinations are carried out on the products thus obtained.

15 The epoxidation reaction between olefin and hydrogen peroxide is conducted at a temperature of between 0° and 150°C, at a pressure of between 1 and 100 ata.

Moreover, the epoxidation reaction can be carried out in batch or in a fixed bed, in a monophase or biphasic system.

20 The catalyst is stable under the reaction conditions, and can be totally recovered and reused.

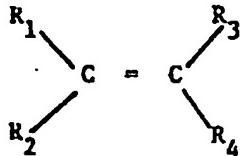
The solvents which can be used include all polar compounds such as alcohols, ketones, ethers, glycols and acids, with a number of carbon atoms which is not too high and is preferably less than 25 or equal to 6.

Methanol or tert.butanol is the most preferred of the alcohols, acetone is the most preferred of the ketones, and acetic or propionic

acid the most preferred of the acids.

The olefinic compounds which can be epoxidated according to the invention are of general formula

5



- where R_1 , R_2 , R_3 and R_4 , which can be the same or different, can be H, or an alkyl, alkylaryl, cycloalkyl or alkylcycloalkyl radical, the alkyl radical having between 1 and 20 carbon atoms, the alkylaryl radical having between 7 and 20 carbon atoms, the cycloalkyl radical having between 6 and 10 carbon atoms, and the alkylcycloalkyl radical having between 7 and 20 carbon atoms.
- 10 The radicals R_1 , R_2 , R_3 and R_4 can constitute saturated or unsaturated rings in pairs.

- 15 Finally, the radicals R_1 , R_2 , R_3 and R_4 can contain halogen atoms, preferably Cl, Br or I, and nitro, sulphonic, carbonyl, hydroxyl, carboxyl and ether groups.

- By way of example, the olefins which can be epoxidated by this process are ethylene, propylene, allyl chloride, butene-2, 1-octene, 20 1-tridecene, mesityl oxide, isoprene, cyclooctene and cyclohexene. Operating at a pressure exceeding atmospheric pressure is useful if gaseous olefins are used, so as to allow them to be solubilised or liquefied under the reaction conditions. Operating at a temperature exceeding 0°C has an effect on the reaction rate, although this is 25 high even at temperatures close to 0°C.

The manner of operating the process according to the present invention and its advantages will be more apparent from an examination of the

following illustrative examples, which however are not limitative of the invention.

EXAMPLES 1-20

1.5 g of powdered catalyst, 45 cc of solvent and 1 mole of olefin
5 are fed into a 250 cc glass autoclave (olefins which are gaseous at ambient temperature are fed with the autoclave sub-cooled).
The autoclave is immersed into a bath temperature-controlled at the required temperature, and 0.3 to 0.6 moles of aqueous H₂O₂ (36% w/v)
are fed by a metering pump over a period of 5-10 minutes, under
10 magnetic agitation.

The residual H₂O₂ is checked periodically by withdrawing a solution sample and iodometrically titrating it. When it has practically disappeared, the autoclave is returned to ambient temperature, and the solution analysed by qualitative and quantitative gas chromatography.
15

The results obtained with various olefinic substrates and the relative reaction conditions are listed in Table 2.

The same epoxidation reactions can also be conducted in a fixed bed, as indicated in the following examples.

20 EXAMPLES 21-31

3.5 g of catalyst having a particle size distribution of 25-60 mesh are placed in a 6 x 4 mm steel tube 45 cm long and having a volume of 5 cc. A solution containing 200 ml of solvent and 20-40 g of olefin is prepared in a steel autoclave (in the case of olefins which are gaseous at ambient temperature, the autoclave is pressurised at 25 15°C with the same olefin until the required weight quantity has been attained). The tube containing the catalyst is immersed in a

temperature-controlled bath, and pumping of the olefin solution is commenced simultaneously with the pumping of the aqueous H_2O_2 solution by means of two metering pumps, the throughputs being regulated so that the molar H_2O_2 /olefin feed ratio is between 10 and 5 90%.

The operating pressure is regulated by means of a suitable valve at the catalytic reactor outlet to a pressure of between 1.5 and 10 15 ata and in any case greater than the pressure in the autoclave containing the olefin. The effluent is percolated through a condenser at 10°C in order to condense all the condensable products, and is then collected and analysed by gas chromatography.

The results obtained are shown in Table 3.

EXAMPLES 32-34

To demonstrate that the H_2O_2 concentration has no effect on the 15 epoxide-glycol distribution, Table 4 shows by way of example the results obtained with allyl chloride in methanol, under the operating conditions of Examples 1-20.

EXAMPLE 35

20 40 cc of isopropanol and 10 cc of water are fed into a 250 cc steel autoclave lined with teflon.

The autoclave is immersed in a bath temperature-controlled at 135°C, and pressurised to 35 ata with oxygen, the quantity absorbed being continuously made up.

After an O_2 absorption of 0.2 moles (4.48 normal litres) the mixture 25 is cooled, depressurised and the quantity of H_2O_2 and peroxides in the solution titrated. It contains 0.155 moles of peroxide oxygen (evaluated as H_2O_2).

0100119

- 9 -

40 cc of said solution are transferred to a glass autoclave together with 10 cc of H_2O_2 and 1 gram of titanium silicalite. 5 g of propylene are fed by sub-cooling the autoclave. The autoclave is then immersed under magnetic agitation into a bath temperature-controlled at 20°C. After 35 minutes the solution is analysed by gas chromatography and titrated to obtain the peroxide content. The following results are obtained:

residual peroxides (as H_2O_2)	5.5 umoles
propylene oxide	110 umoles
10 propylene glycol	8.5 umoles

and thus:

H_2O_2 conversion (peroxides) = 95.56%

propylene oxide selectivity = 92.83%

0100-119

TABLE I

TS - 1		Silicalite (a)			
$2\theta'$	Inter-	(b)	$2\theta'$	Inter-	(b)
(Cuk \bar{A}) planar		(Cuk \bar{A}) planar			
distance d(\AA)					distância d(\AA)
7.94	11.14	vs	7.94	11.14	vs
8.85	9.99	s	8.85	9.99	s
9.08	9.74	m	9.08	9.74	m
13.21	6.702	w	13.24	6.687	w
13.92	6.362	mw	13.95	6.348	mw
14.78	5.993	mw	14.78	5.993	mw
15.55	5.698	w	15.55	5.698	w*
15.90	5.574	w	15.90	5.574	w
17.65	5.025	w	17.65	5.025	w
17.81	4.980	w	17.83	4.975	w
20.37	4.360	w	20.39	4.355	w
20.85	4.260	mw	20.87	4.256	mw
23.07	3.855	s	23.08	3.853	s
			23.28	3.821	ns
23.29	3.819	s			
			23.37	3.806	ns
			23.71	3.753	ns
23.72	3.751	s			
			23.80	3.739	ns
23.92	3.720	s	23.94	3.717	s

0100119

- 11 -

		24.35	3.655	mw	
24.41	3.646	m		-	
		24.60	3.619	mw	
		25.84	3.448	w	
25.87	3.444	w		-	
		25.97	3.431	w	
26.87	3.318	w*	26.95	3.308	w*
			29.23	3.055	w
29.27	3.051	mw		-	
		29.45	3.033	w	
29.90	2.988	mw	29.90	2.988	mw
30.34	2.946	w	30.25	2.954	w
45.00	2.014	mw*	45.05	2.012	mw*
45.49	1.994	mw*	45.60	1.989	mw*

a) Prepared by the method of U.S. Patent 4,061,724; product calcined at 550°C.

b) vs: very strong; s: strong; ms: medium-strong; m: medium; mw: medium-weak; w: weak; *: multiplet.

0100119

TABLE 2

N°	OLEFIN	SOLVENT	t(hours)	T°C	F.R.	H ₂ O CONV.	EPOXIDE SELECT.	GLYCOL SELECT.	OTHERS
1	ETHYLENE	CH ₃ OH	0.5	0°C	50%	99%	85%	5%	10% as glyme
2	"	ACETONE	0.5	25°C	50%	99%	80%	10%	10% as ketal
3	"	t-butyl alc.	0.5 ~	20°C	50%	97%	96%	4%	
4	PROPYLENE CH ₃ OH		0.5	0°C	58%	100%	86%	5%	9% as ether
5	"	ACETONE	0.5	40°C	40%	97%	80%	10%	10% as ketal
6	"	t-butyl alc.	0.8	40°C	50%	90%	96%	4%	
7	"	H ₂ O	1	20°C	50%	98%	72%	28%	
8	ALLYL CHLORIDE	CH ₃ OH	0.2	70°C	58%	100%	95%	1%	4% as ether
9	"	ACETONE	0.5	70°C	50%	97%	96%	1%	3% as ketal
10	BUTENE-2 CH ₃ OH		0.5	20°C	40%	100%	85%	5%	10% as ether
11	"	ACETONE	0.8	40°C	50%	98%	82%	10%	8% as ketal
12	"	H ₂ O	1	25°C	45%	98%	75%	25%	
13	OCTENE 1 CH ₃ OH		1	65°C	35%	100%	85%	15%	10% as ether
14	"	ACETONE	1	60°C	35%	100%	85%	10%	5% as ketal
15	"	-	2	75°C	30%	100%	83%	17%	
16	1-TRIDECENE ACETONE		1.5	80°C	30%	95%	92%	8%	

TABLE 2. (contd.)

	WEIGHT%	OXIDE	ACETONE	1.5	80°C	25%	97%	94%	6%
17									
18	ISOPRENE	CH ₃ OH	0.5	90°C	45%	93%	89%	10%	1%
19	CYCLOOCTENE	ACETONE	1.5	60°C	30%	98%	97%	3%	
20	CYCLOHEXENE	ACETONE	1.5	75°C	35%	99%	98%	2%	

moles H₂O₂ fed

moles olefins fed

* F.R. = feed ratio

TABLE : 3

N°	OLEFIN.	SOLVENT.	T°C	P.R.	PRODUCTIV. Kg/h x 1	H ₂ O ₂ CONVERS.	SELECT.	GLYCOL SELECT.	OTHERS ~ %
21	ETHYLENE	CH ₃ OH	10	45 %	3.02	99%	88 %	3%	9% as glycol monomethyl ether
22	"	ACETONE	10	50 %	2.00	92%	91%	5%	4% as glycol ketal
23	PROPYLENE	CH ₃ OH	15	68 %	4.15	98%	88.5%	1.5%	10% as glycol monomethyl ether
24	"	ACETONE	15	55 %	1.55	90%	92%	6%	2% as glyco 1 ketal
25	"	t-butyl alco.	20	55 %	2.20	85%	85%	4%	
26	ALLYL Chloride	CH ₃ OH	70	60 %	8.52	100%	98%	1%	1% as glycol mono. eth r
27	"	ACETONE	70	60 %	4.53	92%	98%	2%	
28	BUTENE-2	CH ₃ OH	40	45 %	5.35	98%	77%	20%	3% as glycol monoster
29	"	ACETONE	40	50 %	3.70	92%	75%	15%	10% as ketal
30	OCTENE-1	ACETONE	80	35 %	2.35	99%	80%	15%	5% as ketal
31	CYCLOHEXENE	CH ₃ OH	80	40 %	2.12	99%	83%	7%	10% as glyo 1 monomethyl ether

- 14 -

Q100119

0100119

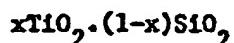
- 15 -

TABLE 4

N°	SOLVENT	H ₂ O ₂ CONC.	F.R.	t(hours)	T°C	EPOXIDE SEL.	GLYCOL SEL.	OTHERS
		% w/v						
32	CH ₃ OH	10%	40%	0.5	15°C	85.2%	5.5%	9.3%
33	" "	30%	40%	0.5	15°C	86.0%	6.2%	7.8%
34	" "	60%	40%	0.5	15°C	84.7%	4.8%	10.5%

CLAIMS:

1. A process for the epoxidation of olefinic compounds, characterised by reacting said compounds with hydrogen peroxide either introduced as such or produced by substances capable of 5 generating it under the reaction conditions, in the presence of synthetic zeolites containing titanium atoms, of the following general formula:



where x lies between 0.0001 and 0.04, and possibly in the presence 10 of one or more solvents.

2. A process as claimed in claim 1, characterised in that the epoxidation reaction is conducted at a temperature of between 0° and 150°C, and at a pressure of between 1 and 100 ata.

3. A process as claimed in claim 1, wherein the hydrogen peroxide 15 is in dilute aqueous solution.

4. A process as claimed in claim 1, wherein the hydrogen peroxide in the aqueous solution is between 10 and 70% v/v.

5. A process as claimed in claim 1, wherein the solvent is polar.

20 6. A process as claimed in claim 5, wherein the polar solvent is chosen from alcohols, glycols, ketones, ethers and acids, having a number of carbon atoms less than or equal to 6.

7. A process as claimed in claim 6, wherein the alcohol is methanol or tert.butanol.

25 8. A process as claimed in claim 6, wherein the ketone is acetone.

9. A process as claimed in claim 6, wherein the acid is acetic

0100119

- 2 -

acid or propionic acid.

10. A process as claimed in claim 1, wherein the olefinic compound is chosen from ethylene, propylene, allyl chloride, butene-2, 1-octene, 1-tridecene, mesityl oxide, isoprene, cyclooctene and
5 cyclohexene.

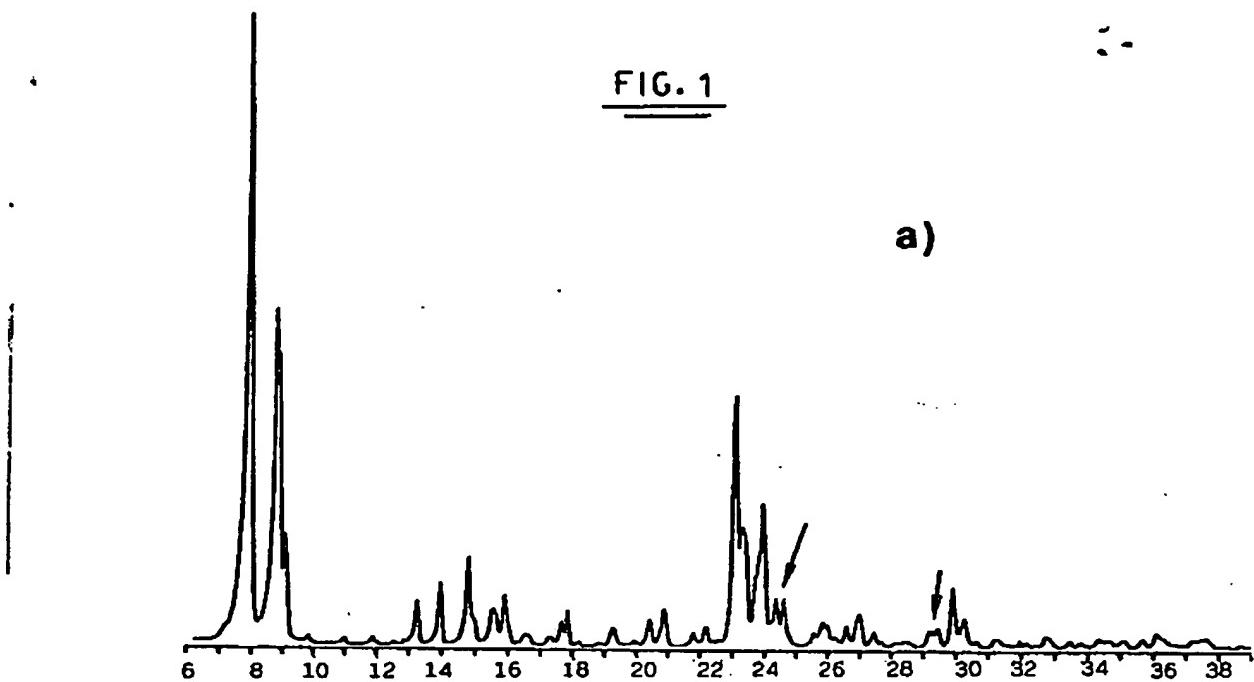
Instrumental Data

0100119

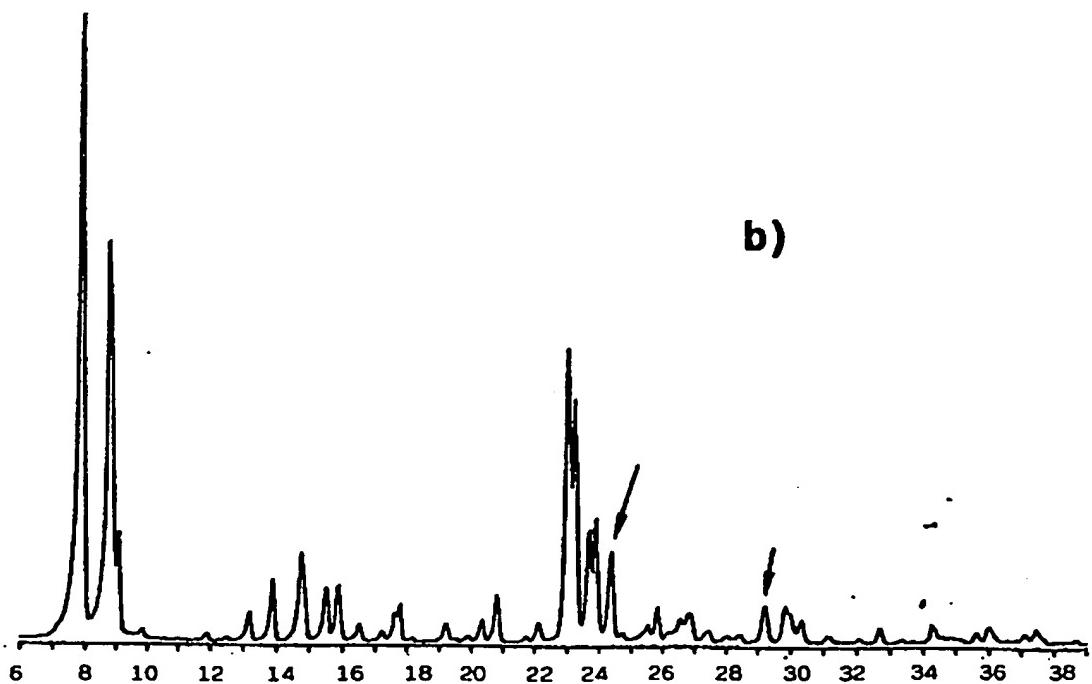
1/2

FIG. 1

a)



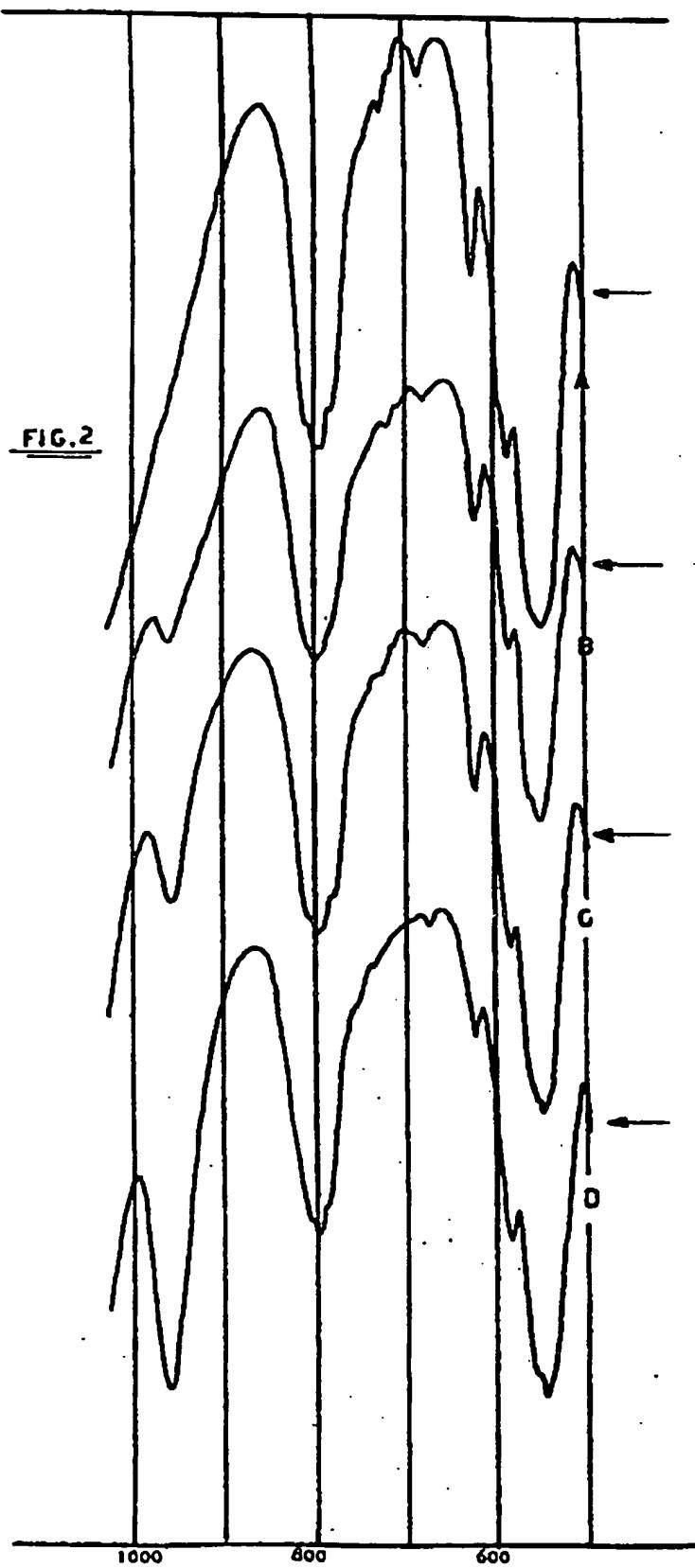
b)



1000 900 800 700 600

8/3

0100119





European Patent
Office

EUROPEAN SEARCH REPORT

0100119
Application number

EP 83 20 1040

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
Y	GB-A-1 583 398 (PRODUITS CHIMIQUES UGINE KUHLMANN) * Whole document *	1-10	C 07 D 301/12 C 07 D 303/04
Y	GB-A-2 083 816 (ANIC SpA) * Whole document *	1-10	
Y	US-A-2 870 171 (C.M. GABLE) * Whole document *	1-10	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
			C 07 D 301/00 C 07 D 303/00
The present search report has been drawn up for all claims			
Place of search THE HAGUE	Date of completion of the search 28-10-1983	Examiner ALLARD M.S.	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			